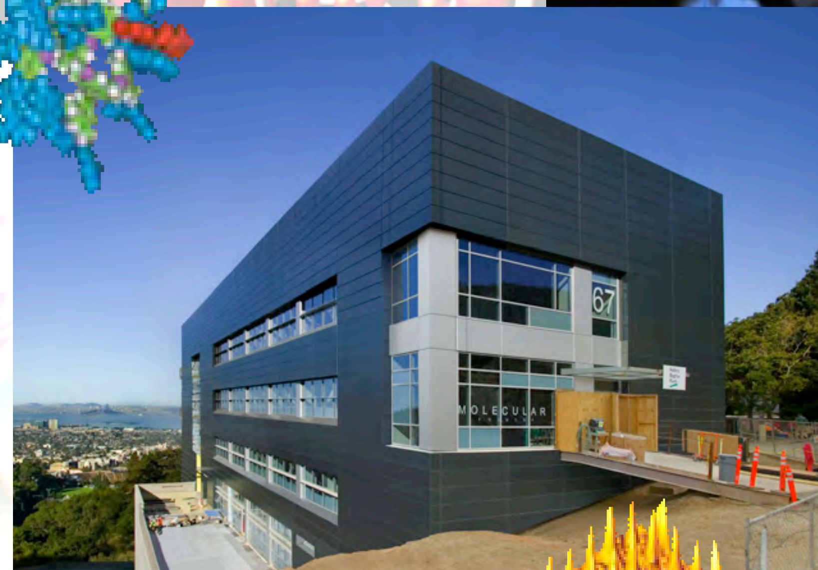
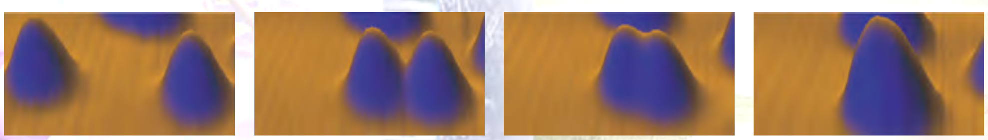
Molecular FOUNDRY
A NANOSTRUCTURES USER LABORATORY

THE MOLECULAR FOUNDRY



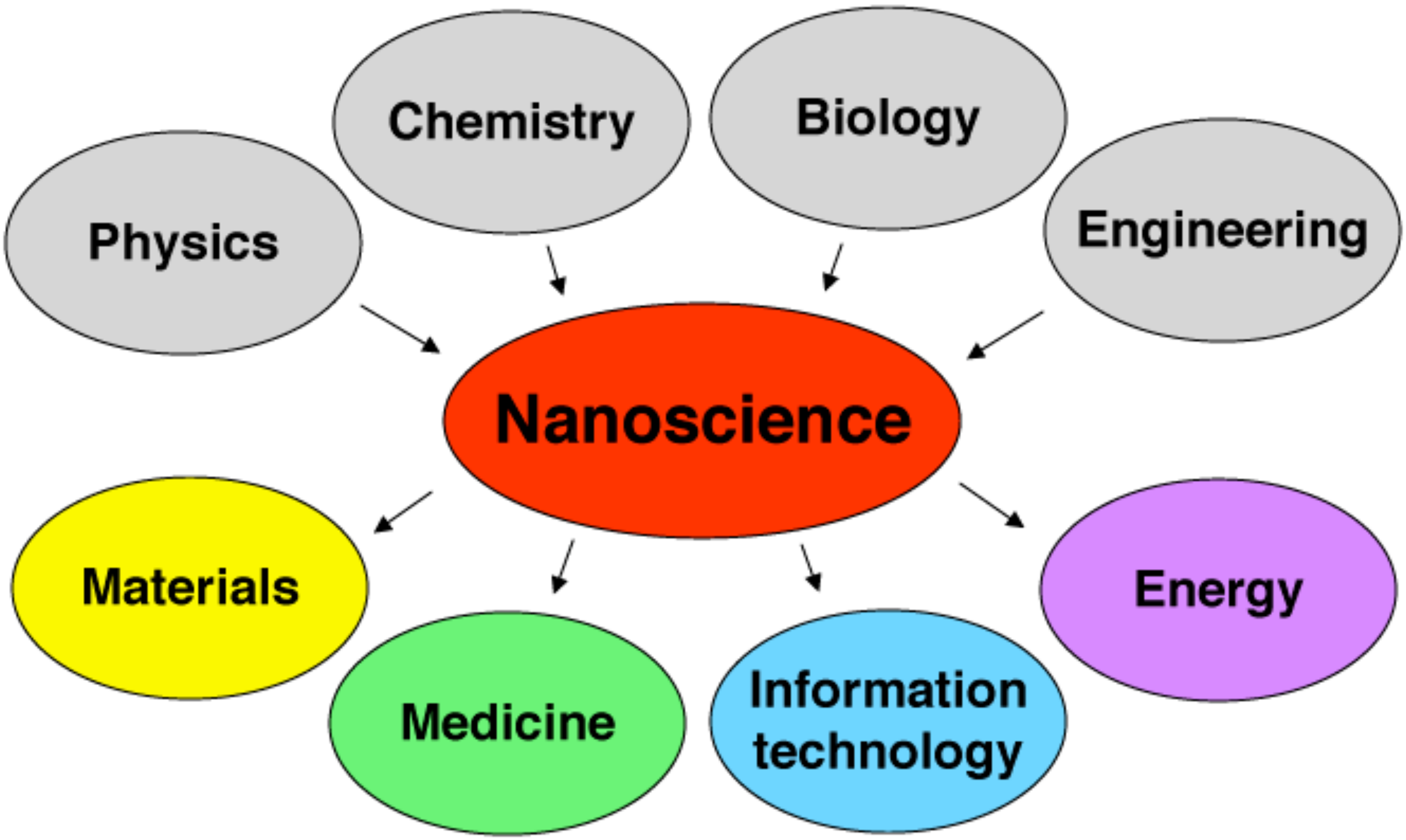
A DOE User Facility for Nanoscale Science Research at Lawrence Berkeley National Lab

Jim De Yoreo, Deputy Director for Research



Office of Science

Nanoscience: *Multidisciplinary* research with *multiple* applications



No one research group can do it all!

Mission of the Molecular Foundry

Purpose

Provide nanoscience capabilities to researchers from any discipline, and any institution, to come, free of charge, to:

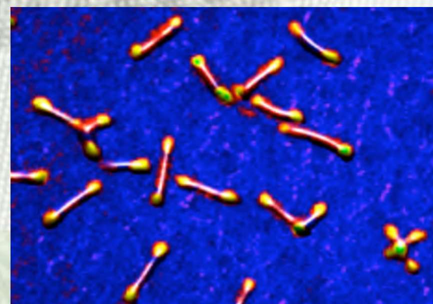
- use state-of-the-art instruments
- learn leading-edge techniques
- collaborate with experts in a wide range of nanoscience disciplines

Impact

….so that they may more effectively pursue their own research interests.

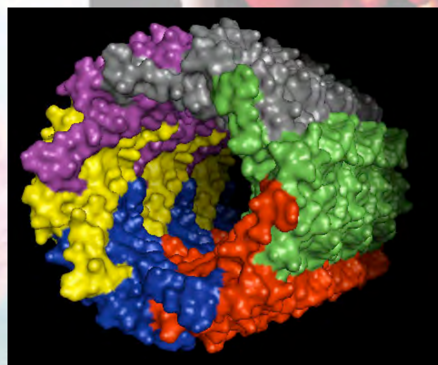
Six facilities, one team

Inorganic Nanostructures



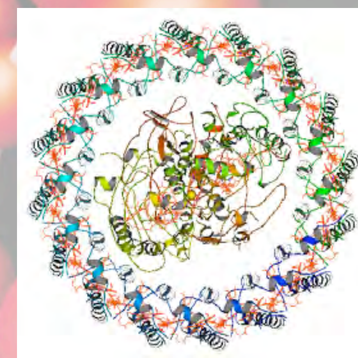
A. Paul Alivisatos

Biological Nanostructures



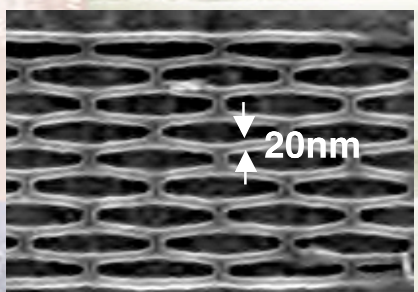
Carolyn Bertozzi

Organic and Macro-molecular Synthesis



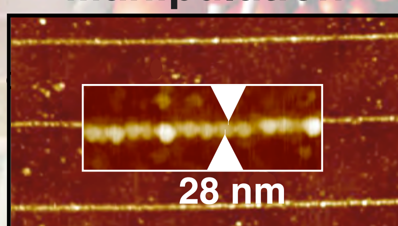
Jean Fréchet

Nanofabrication



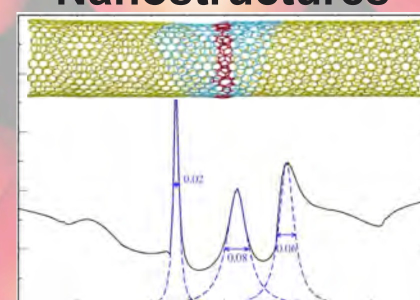
Jeffrey Bokor

Imaging and Manipulation



Miquel Salmeron

Theory of Nanostructures



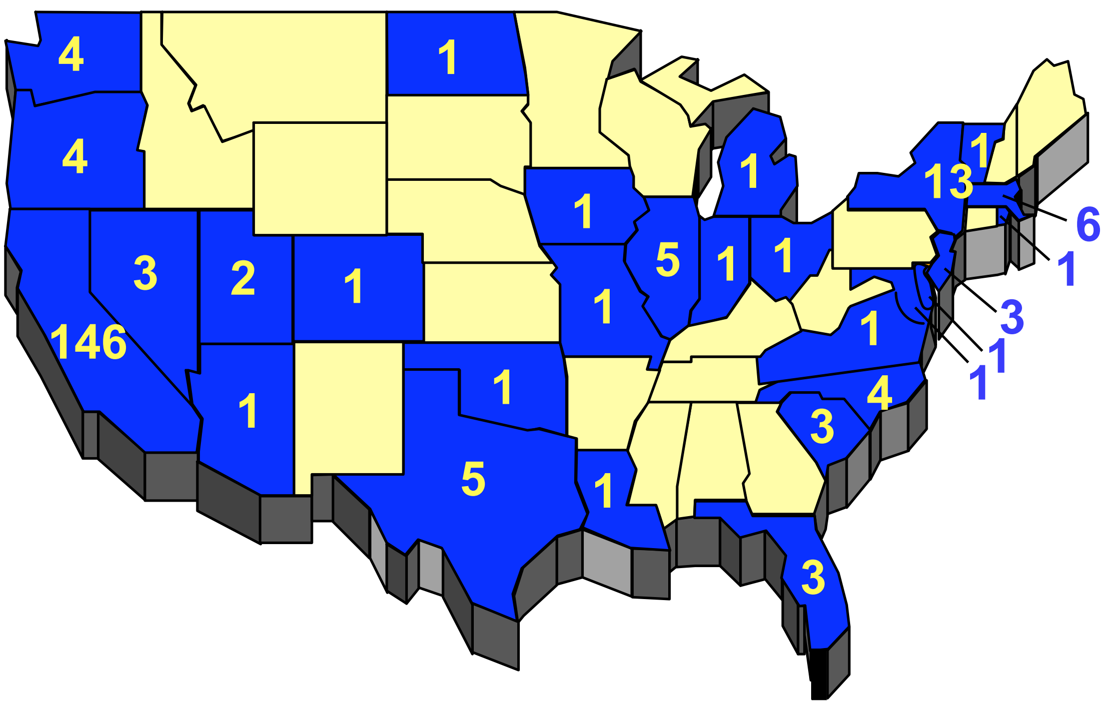
Steven G. Louie

PRESENT AND PROJECTED STAFF

- Director and Deputy Directors
- 6 Scientific Directors
- 29 PhD Scientists (Staff Scientists and Post docs)
- 12 Technical staff (Res. Assoc. and Eng. Assoc.)
- 5 Other (User Program, Outreach, EH&S, IT, Admin.)
- **Present total = 54**
- ~ 6 positions to be filled
- **Total staff projected at steady-state = ~ 60**
- (~ 6 scientists per Facility working with Users)

Users come from around the world

- 459 proposals received, 245 proposals accepted (~ 600 “Users”)
- Academia, Industry, National Labs
- 219 domestic, 26 international
- 28 states and 11 foreign countries represented



+

Australia
Austria
France
Ireland
Italy
Germany
Netherlands
Spain
South Korea
Taiwan
UK

Types of Foundry User Projects

- Obtain nanostructures
- Develop new nanoscale materials/devices and methods
- Learn to use nanoscale materials and methods
- Learn to replicate new instruments/techniques
- Pursue long term collaborations
- Materials only/Instrument only
- Strategic User Partnerships (i.e.,Intel)

NSRCs must also have their own internal research program

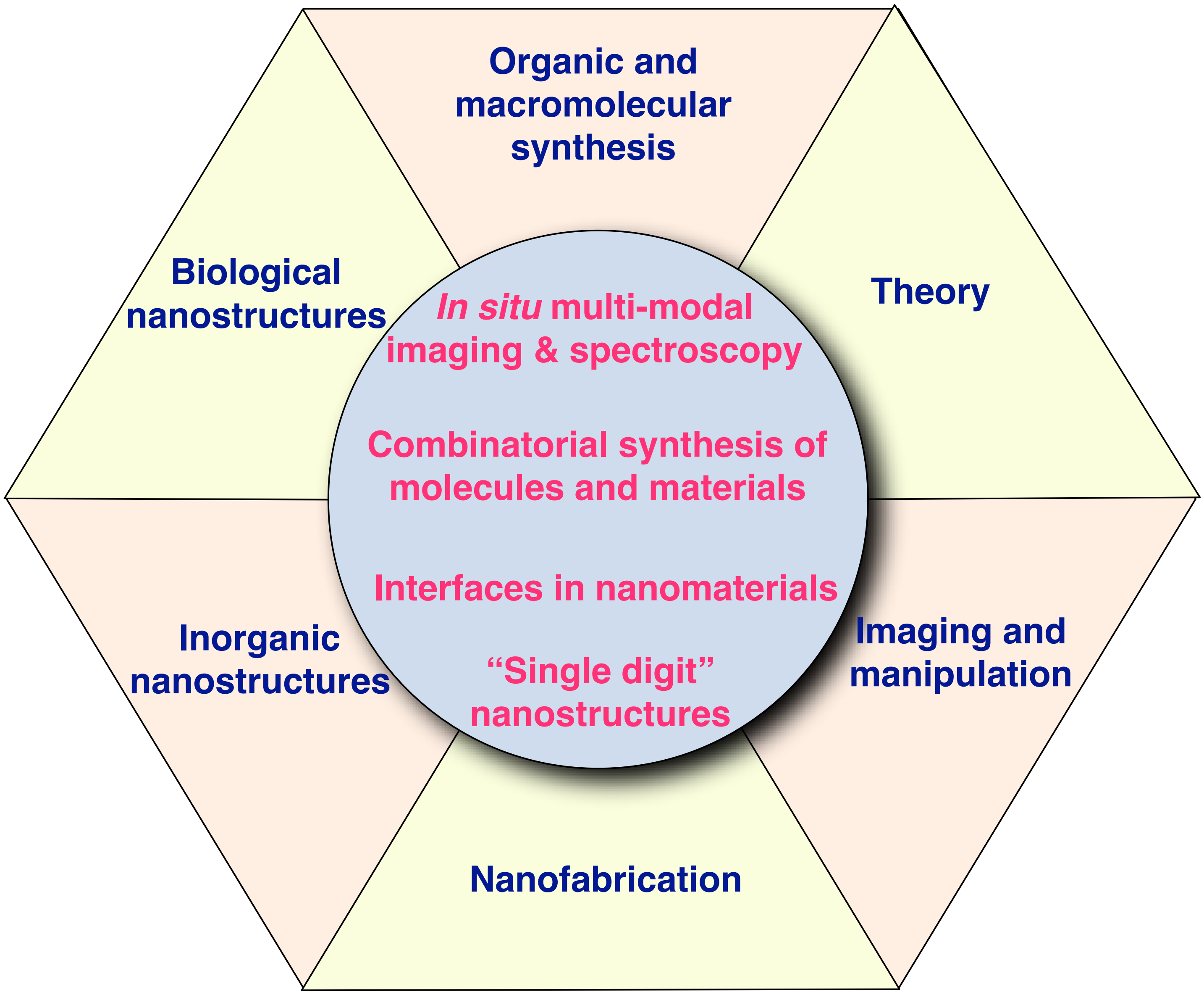
Purpose

Advance the field of nanoscience through a vibrant program of leading edge research

Impact

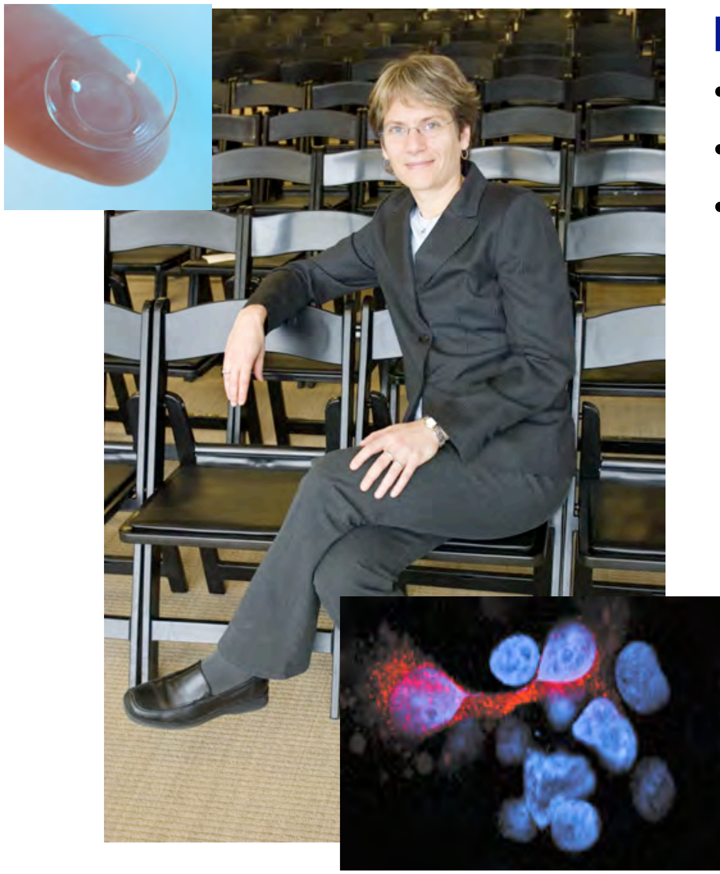
…to provide rapid availability of most advance capabilities in nanoscience to Users

Four research themes integrate the Foundry's six facilities



Biological Nanostructures Facility

Prof. Carolyn Bertozzi, Scientific Director



Expertise:

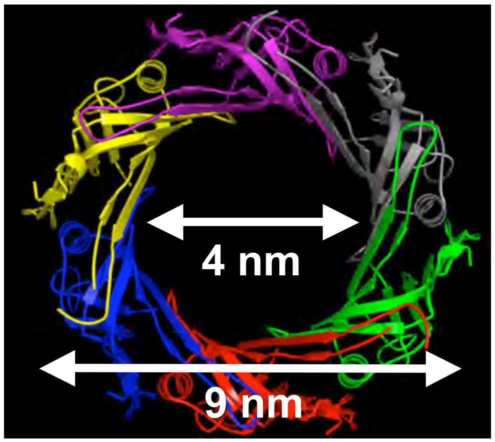
- New nanomaterials inspired by nature
- Nanotechnologies for biological research
- Building nanomaterials from biological components

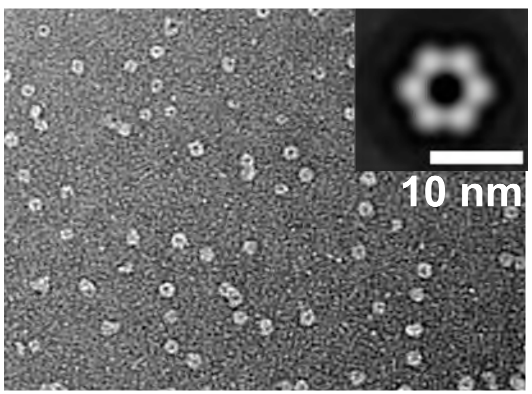
Current capabilities:

- Mammalian, plant, microbial cell culture
- Protein engineering
- RNA preparation
- Bioconjugation chemistry
- Cell immortalization via telomerase expression
- Phage display for nanocrystal-binding proteins/peptides
- Cellular components/products for bio/inorganic assemblies
- Genetic engineering of cell lines for materials integration

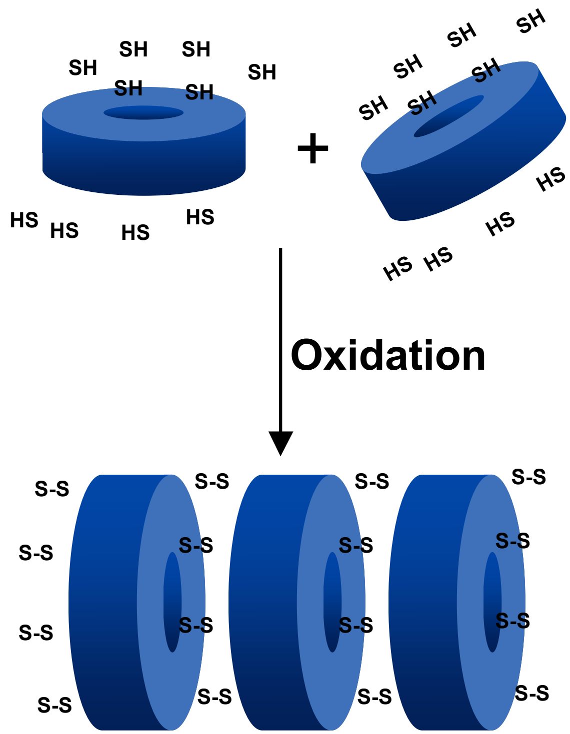
Protein subunits as building blocks

Hcp1 protein forms a ring-shaped hexamer

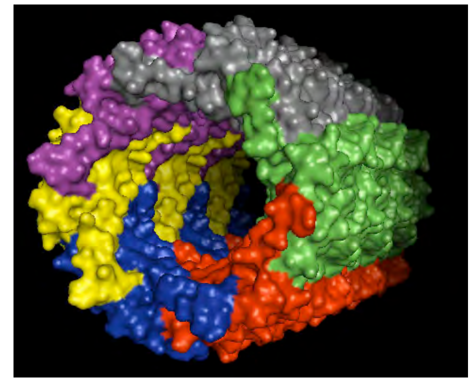


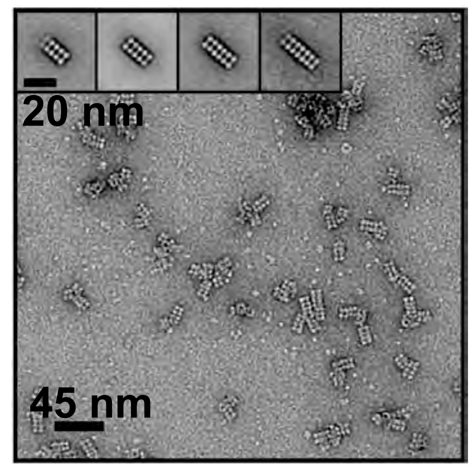


6 cysteines were introduced into each ring face



Rings self-assemble into covalent nanotubes





Can rings be engineered to self- assemble into tubes?

- **Drug delivery**
- **Ion selection**
- **Structural scaffolds**

Foundry User: Joe Mougous

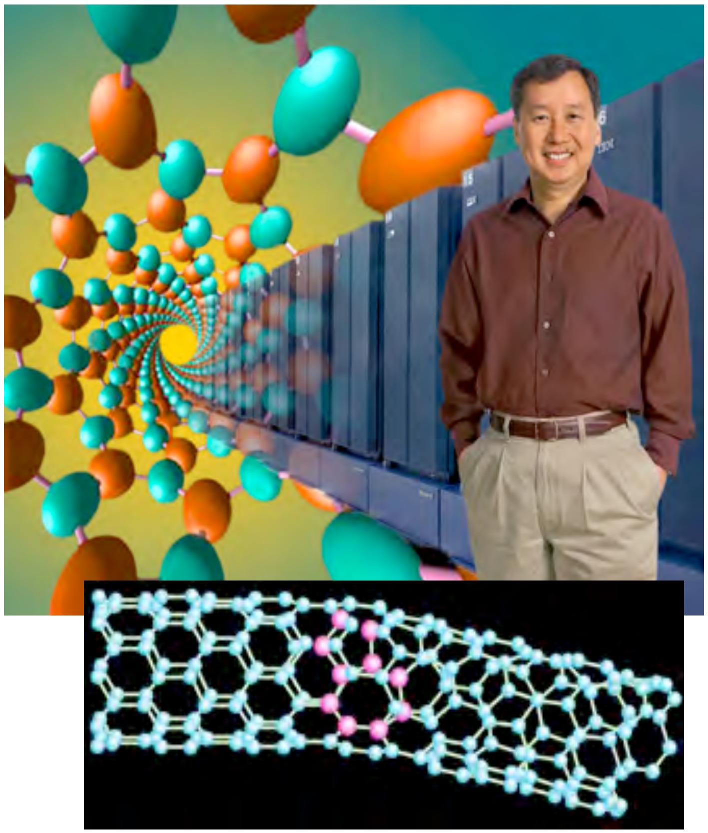
Foundry Staff: Ron Zuckerman

"Single digit" nano

Ballister et al., *PNAS* (2008)

Theory of Nanostructures Facility

Prof. Steven Louie, Scientific Director



Expertise:

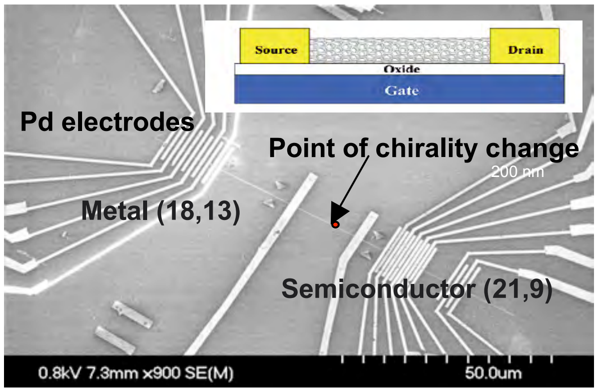
- **Electronic structure of nanomaterials and molecular junctions**
- **Spectroscopic prediction and interpretation**
- **Soft matter assembly and dynamics**

Current capabilities:

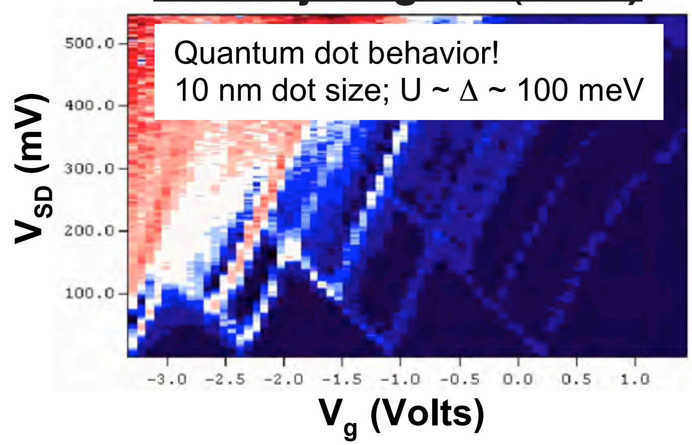
- **First-principles density-functional theory**
- **Classical & *ab initio* molecular dynamics**
- **Excited-state properties with the GW/Bethe-Salpeter equation approach**
- **Electron transport at finite bias with a first-principles scattering-state method**
- **Statistical mechanical approaches**

Carbon nanotube heterojunctions

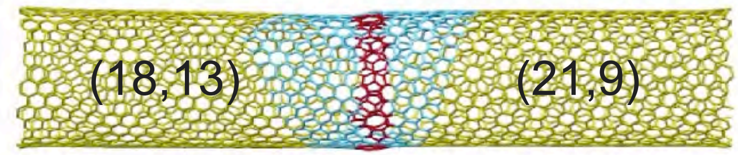
SEM image of (18,13)-(21,9) junction



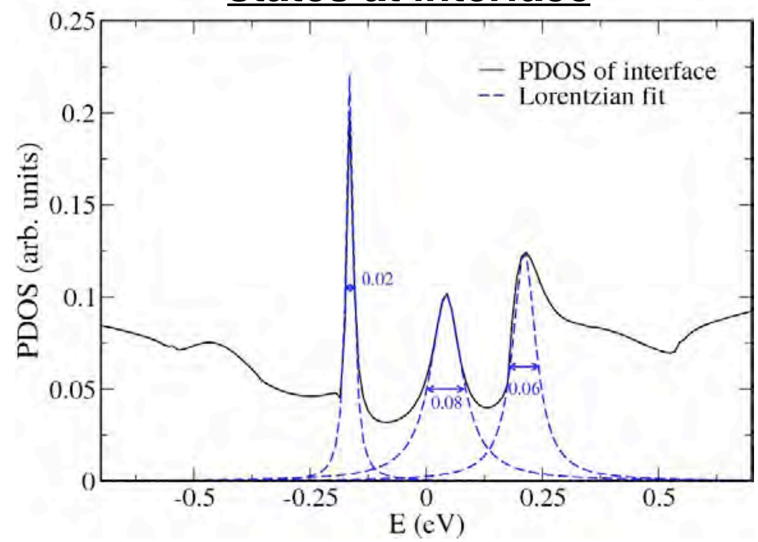
Stability diagram (dI/dV)



Model of SWCNT heterojunction



Prediction of localized states at interface



Why do SWCNT heterojunctions show quantum dot-like behavior?

Defects that accommodate junction led to localized states

Foundry User: Jim Hone, Columbia Univ.

Foundry Staff: J. Neaton and J.Bhattacharjee

Interfaces in nanomterials

Imaging and Manipulation Facility

Prof. Miquel Salmeron, Scientific Director

Expertise:

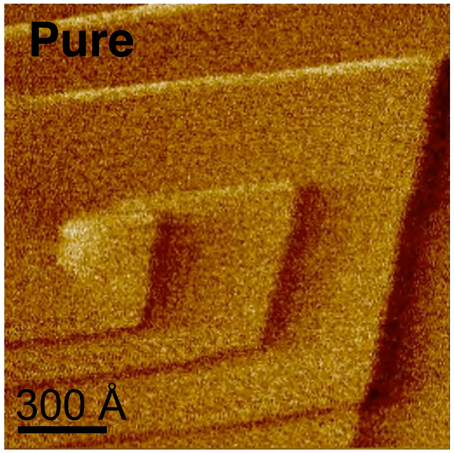
- **Surface science**
- **In situ imaging and spectroscopy**
- **Molecular interactions**

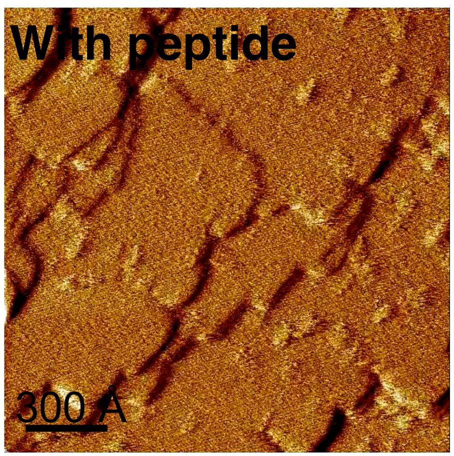
Current capabilities:

- **Electron microscopy**
  - **200 kV Field Emission TEM, Analytical FE-SEM, In-situ SEM, SPM and TEM**
- **Probe microscopy**
  - **Commercial multimode ambient SPM systems (air, liquids, controlled humidity, contact / non-contact)**
  - **Foundry-built ultra-sensitive SPM for chemical interaction work in liquids**
  - **UHV RT-AFM for contact imaging and electrical characterization**
- **Optical spectroscopy**
  - **Tunable ultrafast laser system (Ti:SAF / OPO), super-continuum white source, CW sources**
  - **Photon counters, low noise spectrometers, confocal microscope and cryostat, general optics**
- **Surface Analysis**
  - **Scanning Auger and non-monochromatic XPS**
- **Support**
  - **Optical microscopy, sample prep and chem lab**

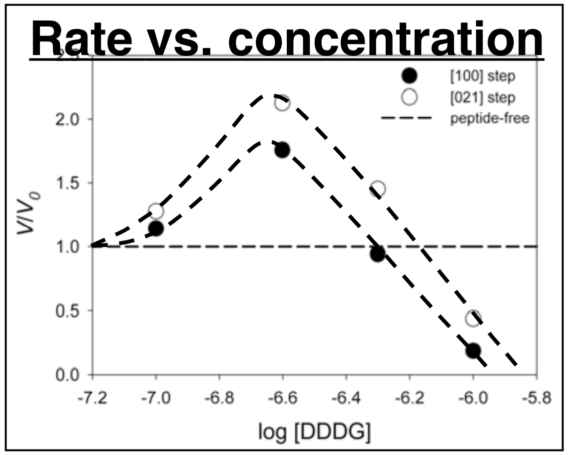
High resolution *in situ* imaging of nanocrystal growth

Surface morphology

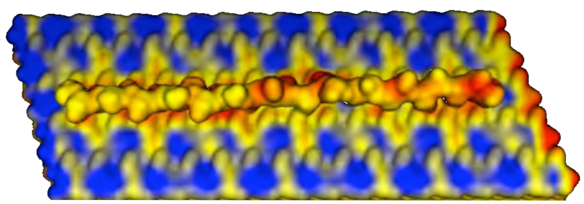




Rate vs. concentration

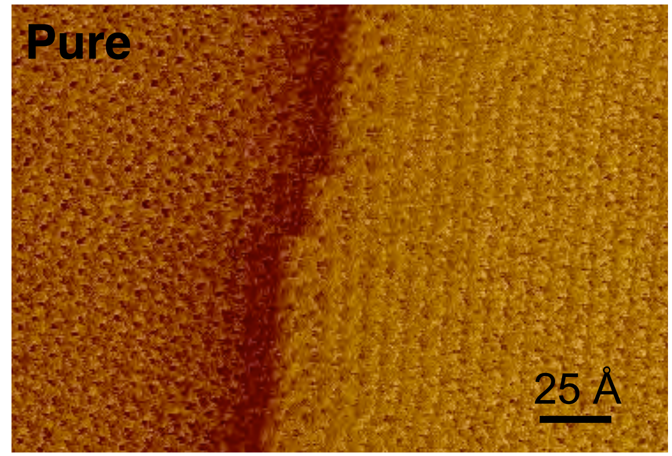


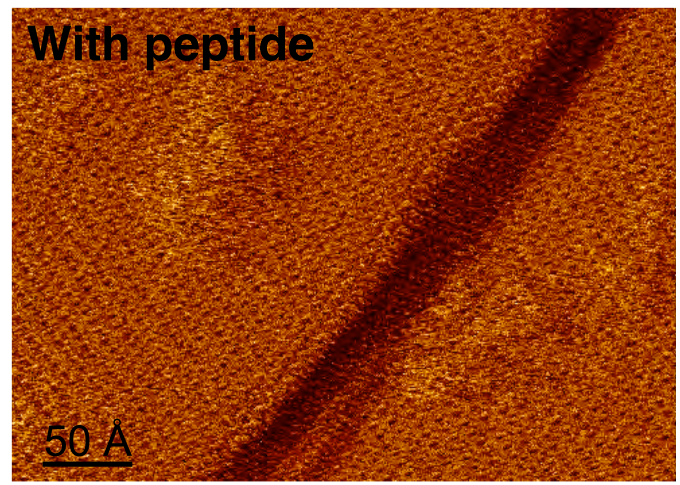
Molecular model



How do acidic peptides modify growth of electronegative face?

Develop atomic resolution imaging

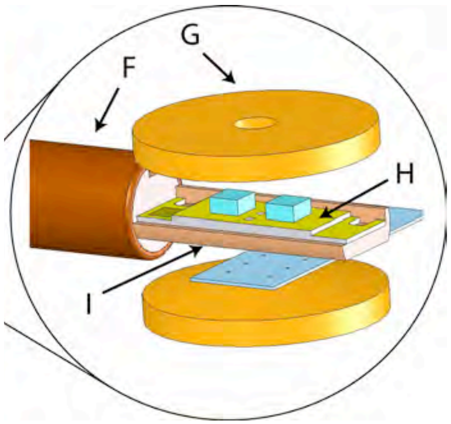


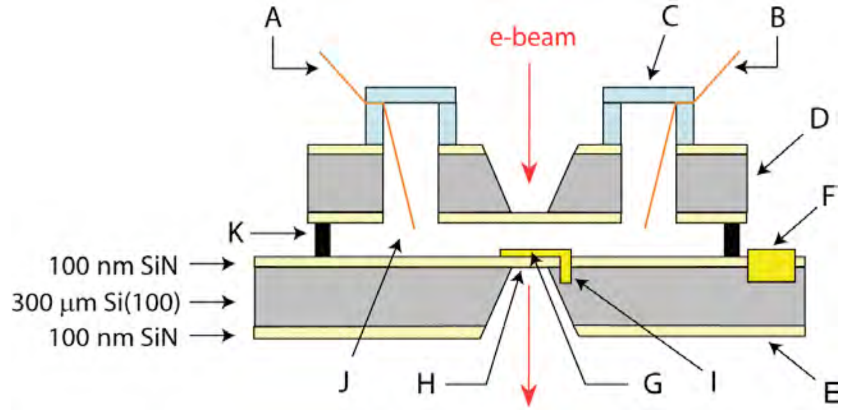


Peptides adsorb as highly charged clusters

In situ multimodal imaging

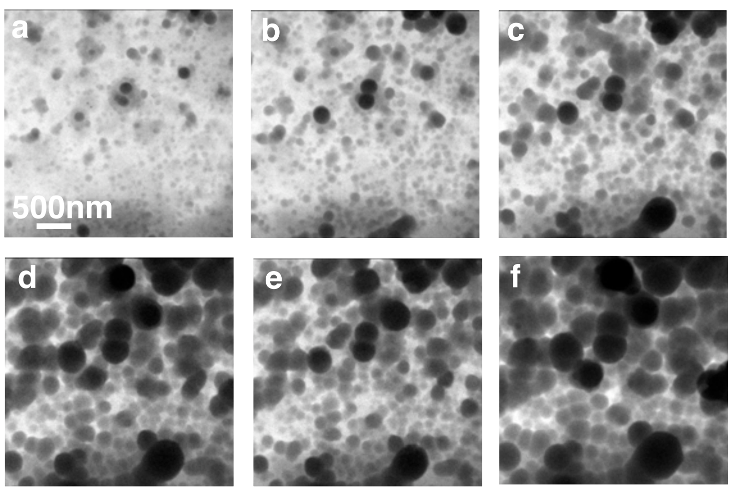
Working with NCEM to develop fluid cells for *in situ* TEM studies of nucleation and assembly





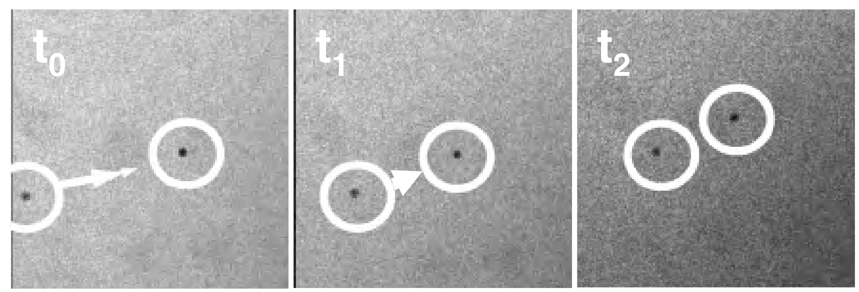
- Closed system
- Electrochemical & temperature control (0-70°C)

Growth of silicone-based colloids



~25s intervals through 1μm cell

Diffusion of 4nm Au nanoparticles

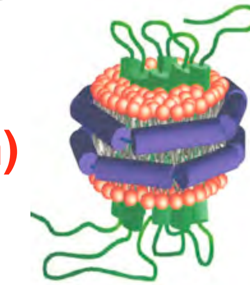


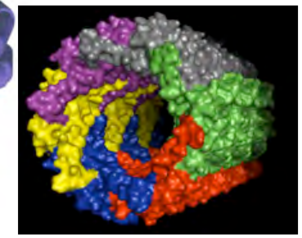
Examples illustrate ability to follow dynamics of assembly and growth

In situ TEM will enable Users to probe nanomaterials assembly and reactivity

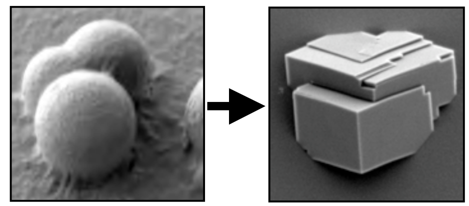
Soft matter and organic-inorganic interfaces

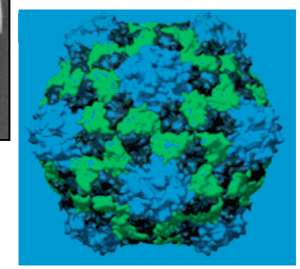
- **Assembly of macromolecular complexes (Zuckerman)**
  - **Protein nanotubes, Nanolipid disks**



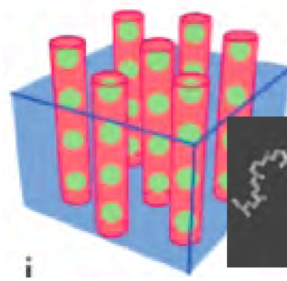


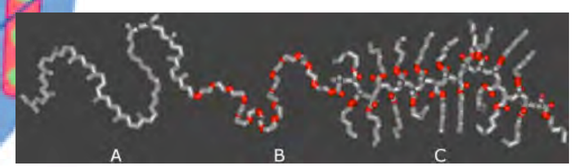
- **Bio-templated assembly (DeYoreo)**
  - **Silicateins, Protein cages, Peptides**





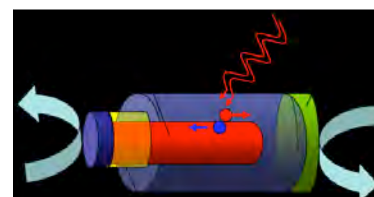
- **Supramolecular structures (Liu)**
  - **Block co-polymer scaffolds**

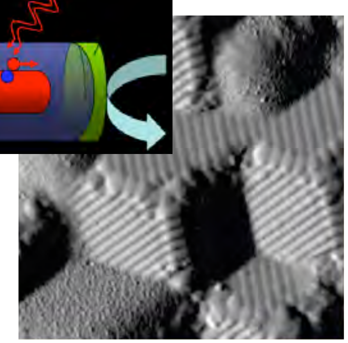




Inorganic nanostructures

- **Catalysis at nanoparticle surfaces (Aloni, Salmeron)**
  - **Photovoltaics, Solar-to-fuel catalytic structures**





- **Nanowires (Mokari)**
  - **Solution-liquid-solid growth**